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SURFACE ROUGHNESS METER

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page 6, Fig 1
two k-s

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No. OF CLAIMS 12

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incidence of light gives a reflectance which is greatly influenced by the rms slope of the surface profile and so reflection results are entirely different with the same rms surface roughness when the surface roughnesses have different rms slopes. This has limited the usefulness of gloss meters for quantitative roughness measurements, particularly in the range of from 10 microinches down and at best only gross qualitative indications of poor reproducibility can be obtained.

The present invention utilizes a particular type and organization of two-color photometer to measure roughness. The incident light used is normally in a very narrow angle about normal incidence and great accuracy is obtainable, far beyond anything given by a profilometer even with very hard material particularly in the range below 5 microinches. It has been determined that at normal incidence the reflection is an exponential function of the square of the rms roughness in which the ratio of rms roughness to the wavelength reflected is a factor in the exponent. The instruments of the present invention translate the ratio of reflectances at two different wavelengths into a result from which the surface roughness can be derived, preferably automatically by the operation of the instrument. Instruments using the difference of the reflectances are also useful but somewhat less precise.

As stated above, the instrumental solution of the problem might appear prima facie feasible. However, there are other factors which render a direct solution, generally applicable to all ranges of roughness impossible, or so complex as to be impractical.

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radiation be available it is not necessary that this small spread be fixed and for some purposes an instrument which permits readings at small angular spread and at a larger one has uses and is, therefore, not excluded from the present invention.

When used in its normal mode with the small angular spread of radiation beam and the other limiting factors the present instrument performs something that has not been possible with optical instruments of the gloss meter type, namely the measurement of rms roughness with high precision regardless of variation in the rms slope of the surface irregularities and regardless of whether the roughness is random or oriented. This new result is of great practical importance.

While the radiations used in the instrument can be any optical radiation, (i.e. ultraviolet, visible or infrared), the preferred results are obtained with somewhat longer wavelengths than visible light. For example two wavelength bands in the near infrared are desirable. With sufficiently fine surface roughness an instrument operating on the two-color principle described above can, in principle, be used in visible light only or with one color of the two-color photometer in the visible and the other in the infrared. With these shorter wavelengths color differences sometimes present problems. Surfaces tend to reflect much more like gray bodies in the infrared than in the visible. However, where the nature of the material, the roughness of which is to be measured, permits, radiations in the visible may be used. As most of the practical instruments, according to the present invention, are particularly designed for

In Fig. 1 a radiation source (1), such as an incandescent lamp which radiates in the visible and the near infrared, produces a beam of light which is condensed by the lens (2) and passes through a pinhole (3) in a plate. In a practical instrument this pinhole may be approximately 0.031" in diameter. The beam from the pinhole is focused by a lens (4) and is split by a beam splitter (5). One beam is focused onto the roughness sample or sample holder (6). The light passing through the beam splitter (5) is rejected. From the roughness sample reflected light passes through the beam splitter (5), is collimated by conventional optics (7) and transmitted to a prism (8) which can be pivoted about the point (9) to choose different portions of the spectrum generated at the plane of a mask (11). The dispersed light is then imaged by the lens (10) onto the plane of the mask (11) provided with two slits (12) and (13). The particular spectral bands transmitted by these slits pass through a field lens (14) onto a lead sulfide detector (15). The beams are chopped by a conventional chopper (16) turned by a motor, (not shown). The chopper incorporates conventional reference wave generating means shown diagrammatically as a pickup coil (17) which cooperates with a magnetic insert in the chopper, (not shown). Any other type of reference generator may be used, such as an opening with a light and a photocell. The output from the radiation detector (15) is then introduced into a phase sensitive amplifier (18) which also receives the reference square wave from the pickup (17). The difference in the signals from the two beams through the slits (12) and (13)

(13) should preferably be from 10 to 30 times longer than the rms roughness. For measurements in the range of ~~0.1~~ 1 microinch to about 10 microinches, suitable wavelengths are approximately 0.8μ and about ~~1.5μ~~ 2.5μ. For other ranges of roughness different wavelengths can be used, and this can be effected by turning the prism (8). Ordinarily even for a versatile laboratory instrument a few pairs of wavelengths will suffice and so the movement of the prism may be to a limited number of predetermined positions, for example as determined by conventional stops.

The instrument measures rms roughness in the range referred to above with accuracy and does not damage the surface, something which is impossible in this range with a profilometer. When coarser roughnesses are to be measured, the present instrument is still useful though of course it may be necessary to utilize somewhat longer wave infrared in order to maintain the desired ratio between wavelength and surface roughness. Even in ranges and with hard materials where a profilometer can be used, the present instrument gives a reading which is more constant where the roughness is oriented. When scratches are parallel to each other, the profilometer reading will change depending on the direction in which the stylus is moved across the surface, whereas the optical measurement depends on the spectral effect of the rms roughness value and is substantially insensitive to sample orientation. It, therefore, gives improved results even in a range where the old-fashioned profilometer could be used.

As noted above, the logarithmic transmittance function generated by the wedge (20) results in a wedge

1.5μ. Rays pass through the two filters and then through objective (26), continuing on through the field stop (30) and field lens (31) to illuminate the two halves (27) and (28) of a split detector. Each half receives radiation from a single filter only. In front of the filters is a rotatable cap (25) provided with a suitable angular scale which is not shown. This member has a solid portion (32) and a semicircular opening (29). The cap is shown in Fig. 4 at the position where the beams through the two filters are equally attenuated, (i.e. halved), by the cap. For convenience this setting corresponds to 45° on the angular scale, while at 90° filter (23) is 3/4 open and filter (24) is 1/4 open. At 135° filter (23) is completely opened and filter (24) is completely closed.

The differential output passes through an amplifier (18). The amplifier output registers on a meter (19). The operation of the instrument can best be considered by reciting the sequence of a measurement. First a standard surface is placed at (6). This may be a completely smooth surface with zero rms roughness or it may be a sample of known rms roughness. The cap (25) is then turned until the meter (19) shows zero output. The angular setting of the cap (25) will be designated as θ_1. The sample of which the roughness is to be measured is then inserted and again the cap (25) is turned until once more there is a null reading on the meter. The resulting angular setting of the cap will be designated as θ_2. The ratio of the exposed areas of the two filters is defined by the following fraction:

$$\frac{135° - \theta}{45° + \theta}$$

transformed into the two spectral bands and both come from the same beam. This more complicated instrument permits the measurement of surfaces which are not flat and in fact extends the present invention to curved surfaces such as spherical surfaces of reasonable curvature. It now becomes possible to measure the rms roughness of spheres which is of importance in the ball bearing industry.

While there are limitations to the precision of measurement of different types of samples on the simplified instrument, for a large number of purposes where the samples are reasonably flat the results are entirely satisfactory and so it is possible in such cases to utilize the extremely cheap and compact instrument of Fig. 3. It is an advantage of the present invention that it is very flexible and instruments of differing degrees of complexity and versatility are available so that the best compromise in terms of instrument versatility versus cost can be chosen in each case.

The two Figs. (1) and (3) show two different techniques of producing radiation bands of suitable spectral width. It should be understood that this does not mean that the single beam instrument of Fig. 1 must always employ a monochromator. It is possible to take the single beam and split it with conventional beam splitters and utilize filters. Such variations are, of course, included within the scope of the present invention as recited in the claims.

wavelength bands of the reflected beam, the wavelength of the shorter band being at least ten times as long as the maximum rms roughness to be measured, a radiation detector, means for imaging the two selected narrow bands of the reflected beam thereon, means for attenuating at least one of the narrow bands, means for chopping the radiation located intermediate the light source and the detector, means for generating a reference signal said means being actuated in synchronism with the chopping means, a phase sensitive AC amplifier, means for connecting the output of the radiation detector to the input of said amplifier, and means for indicating polarity and magnitude of the amplifier output whereby said means indicate a function of the relative amounts of radiation in the two bands striking the detector.

4. An optical roughness measuring instrument for measuring rms roughness over a predetermined range comprising, in combination and in optical alignment, a source of optical radiations, means for producing a narrow beam therefrom of suitably low divergence, a roughness sample holder, means for directing said narrow beam onto the surface of said holder at substantially normal incidence to produce a reflected beam, means for selecting two narrow wavelength bands from the reflected beam, the wavelength of the shorter band being at least approximately thirty times as long as the maximum rms roughness to be

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is at least about thirty times the maximum rms roughness to be measured.

9. An optical measuring instrument for measuring rms roughness over a predetermined range comprising in combination and in optical alignment a source of optical radiations, means for producing a beam thereof of suitably low divergence, a roughness sample holder, means for directing said beam onto the surface of said holder at substantially normal incidence to produce a reflected beam, two filters passing different narrow wavelength bands in said beam, the wavelength of the shorter band being at least 10 times as long as the maximum rms roughness to be measured, means for varying the relative cross-sections of the beam striking the filters, radiation detectors in the filtered beams, means for producing a differential output from said detectors and amplifying and indicating means connected thereto.

10. An optical measuring instrument for measuring rms roughness over a predetermined range comprising in combination and in optical alignment a source of optical radiations, means for producing a beam thereof of suitably low divergence, a roughness sample holder, means for directing said beam onto the surface of said holder at substantially normal incidence to produce a reflected beam, two filters passing different narrow wavelength bands in said beam, the wavelength of the shorter band being at least 30 times as long as the maximum rms

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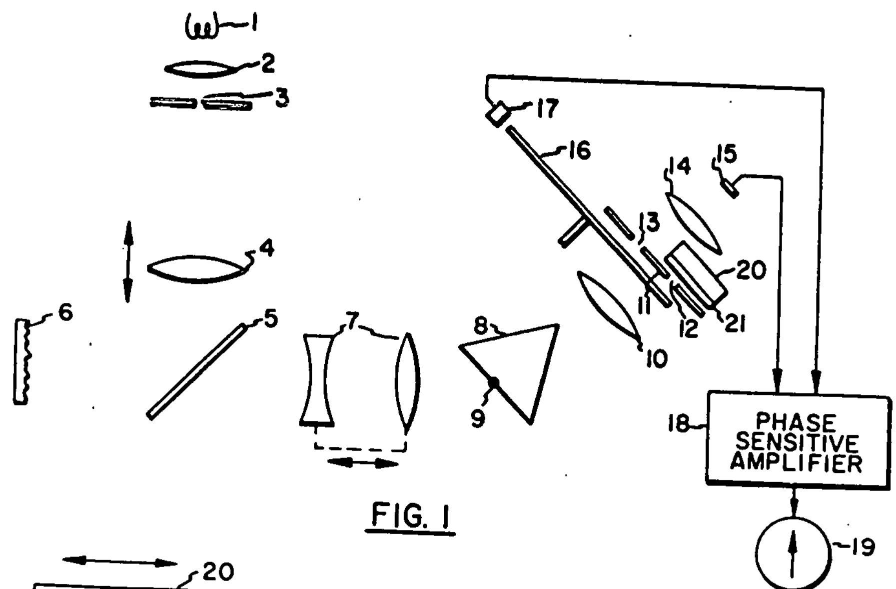

FIG. 1

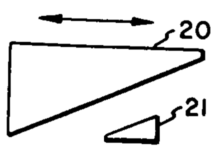

FIG. 2

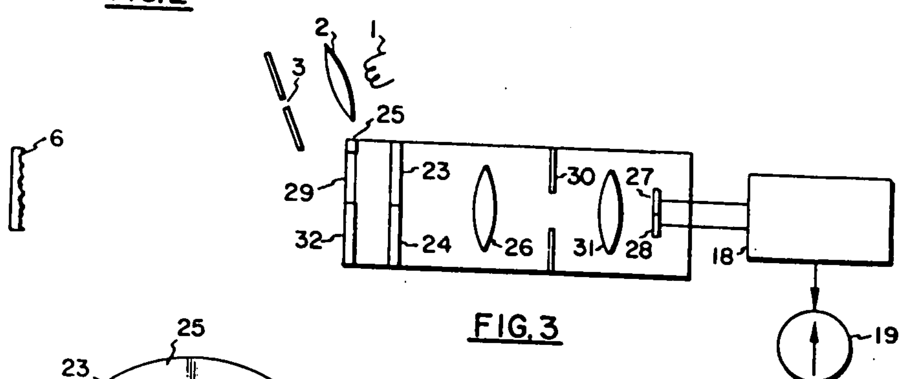

FIG. 3

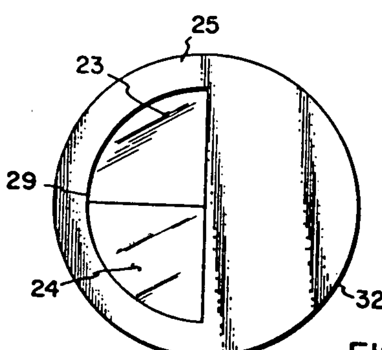

FIG. 4